FORCE BETWEEN TWO PARALLEL CONDUCTORS. Consider that two wires, carrying currents I_1 and I_2 respectively, are parallel over a length l and separated by a distance r. The magnetic induction at a distance r from the wire carrying current I_1 is $B = 2KI_1/r$, and the force on the other wire carrying current I_2 in this field is $F = BI_2l = (2KI_1/r)I_2l$. Hence the force between the parallel wires is

$$F = 2K\frac{I_1I_2l}{r}$$

where F is in newtons, I in amperes, l and r in meters, and $K = 10^{-7}$ nt/amp^2 or weber/amp-m in free space. The force is attractive if I_1 and I_2 are in the same direction; the force is repulsive if I_1 and I_2 are in opposite directions.

The force per unit length is $F/l = 2KI_1I_2/r$. Thus the ampere may be defined as that current which, if existing in each of two infinitely long parallel wires separated by a distance of 1 meter in free space, causes the force on each wire to be 2×10^{-7} newton per meter of length.

TORQUE ON COIL IN MAGNETIC FIELD. The torque L on a coil of N turns carrying current I in a field of magnetic induction B is

$$L = BINA\cos\theta$$

where A is the area of the coil and θ is the angle the plane of the coil makes with the field. When the plane of the coil is parallel to the field, $\cos\theta = \cos 0 = 1$ and the torque is a maximum. When the plane of the coil is normal to the field, the torque is zero.

The torque is given in meter-newtons when B is in nt/amp-m (webers/m^2), I in amp, and A in m^2.

FORCE ON A MOVING CHARGE IN A MAGNETIC FIELD. Consider that a charge q moves with velocity v in a field of magnetic induction B and covers a distance l in time t. Then $l = vt$ and the moving charge represents a current $I = q/t$. Substituting $Il = (q/t)(vt) = qv$ in $F = BIl\sin\theta$, the force on the charge is

$$F = Bqv\sin\theta$$

where θ is the angle between vectors B and v. Consistent mks units are F in newtons, B in webers/m^2, q in coulombs, v in m/sec. The direction of F is perpendicular to the vectors B and v.

PATH OF CHARGED PARTICLE IN MAGNETIC FIELD. When a particle of mass m, charge q and initial velocity v moves normal to a field of magnetic induction B, the force acting on it is $F = Bqv$ directed perpendicular both to B and v. Since F is constant in magnitude and directed always at right angles to v, the particle has uniform circular motion with radius r and centripetal acceleration $a = v^2/r$. Now combining $F = ma = mv^2/r$ and $F = Bqv$, we have $mv^2/r = Bqv$ from which

$$r = \frac{mv}{Bq}$$

A **cyclotron** is used to accelerate massive particles (e.g. protons, deuterons, alpha particles) by applying a small voltage many times in succession as the particles spiral outward in a magnetic field. This is possible because the angular velocity $\omega = v/r = Bq/m$ of a particle is independent of its speed and of the radius of its path, as long as v is small compared with the speed of light.

A **mass spectrograph** is used to determine the masses of positively charged ions, and to measure the relative abundance of isotopes. Positive ions having the same charge q and velocity v enter a uniform magnetic field B perpendicular to the vector v and thus are caused to move in a circular path of radius $r = mv/Bq$. Since v/Bq is the same for all ions, the mass m of the ion is proportional to r.